LABORATORY AND OBSERVATORY FACILITIES

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LABORATORY AND OBSERVATORY FACILITIES

- CANDIDATE PAYLOAD PLANNING
- COMMON MODULE CONCEPTS

NASA HQ MF70-6072
5-20-70

SLIDE 1

LABORATORY AND OBSERVATORY FACILITIES

This presentation will cover two major areas, payload planning and commonality analysis. In order to provide a basis for station design studies, we had to plan how the experiment and research program which the station should be capable of supporting. Once these candidate payloads were identified, we attempted to determine how they could be accommodated. Through contracted studies, we have ascertained that a "common" module approach offers substantial cost savings, flexibility in scheduling and flight and an affordable space research program.

SLIDE 1

LABORATORY AND OBSERVATORY FACILITIES

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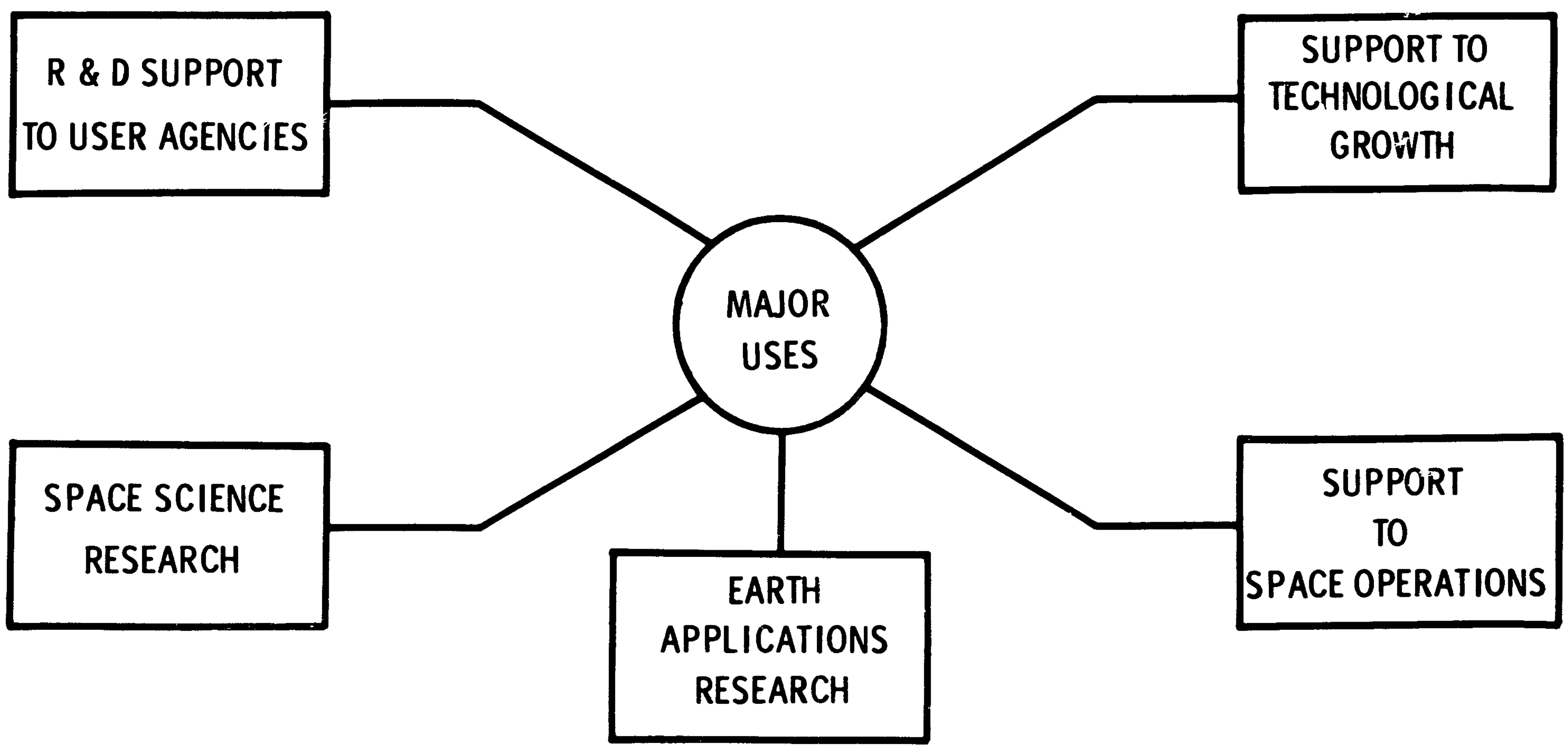
SPACE STATION - AN INTERNATIONAL RESOURCE

PRINCIPAL AREAS OF UTILIZATION



<u>CONCLUSION:</u>

SPACE STATION CAPABLE OF BROAD UTILIZATION

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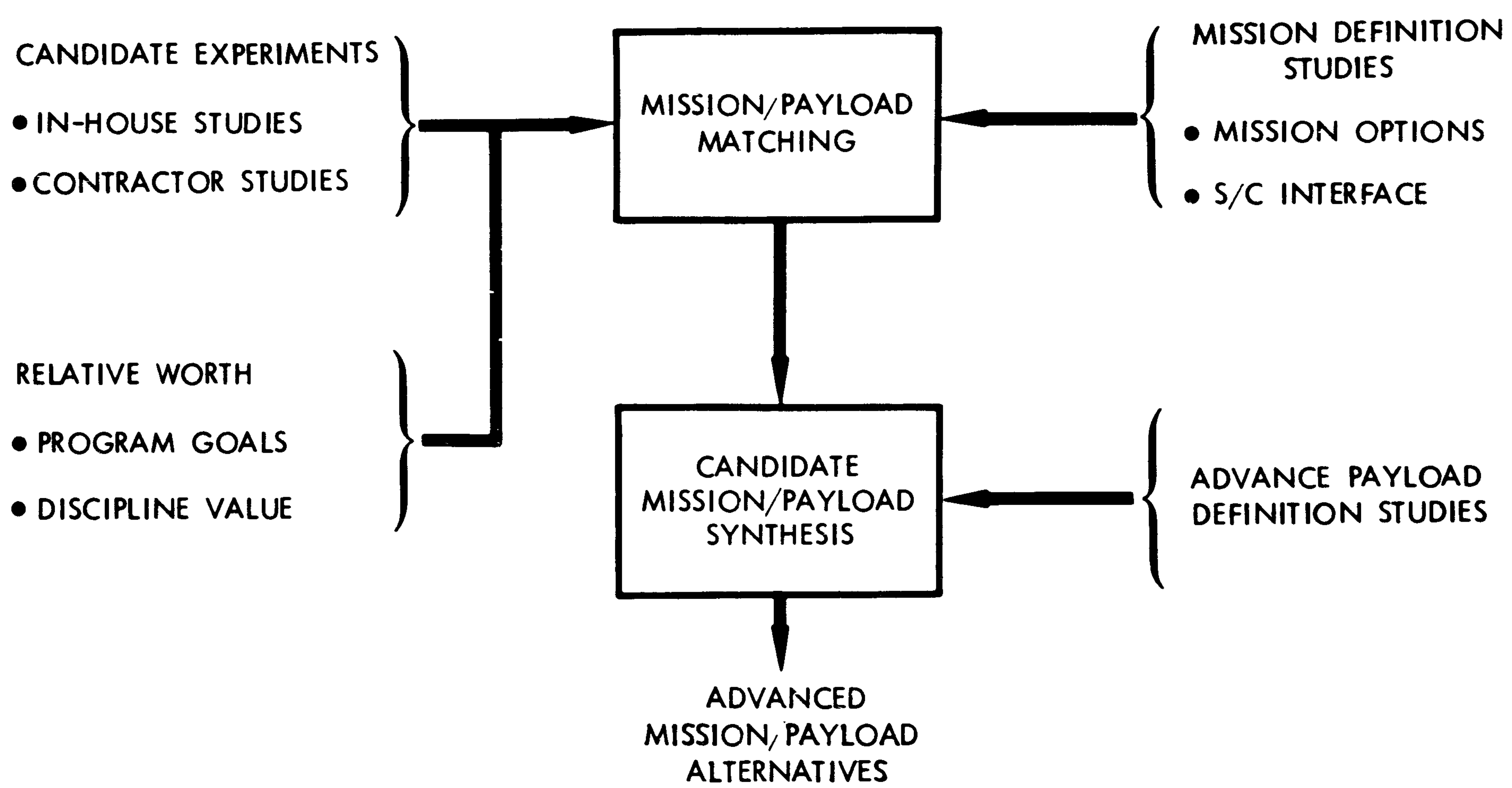
SLIDE 2

EXPRESSION OF INTERNATIONAL NEEDS

The Space Station can be viewed as an international resource which mobilizes the capability to exploit the space environment for the improvement of human welfare and the advancement of science. In this regard its functions tend to group into five major areas of utilization as shown on this chart. It will be noted that the management function associated with this facility is a large and complex one requiring the best techniques of management to assure that all user needs are met effectively and efficiently. Broad opportunties for international participation in research and development of the station, experiment modules and in the experiment and research program are apparent.

ADVANCED EXPERIMENT PROGRAM PLANNING



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SLIDE 3

ADVANCED EXPERIMENT PROGRAM PLANNING

This slide depicts the method by which experiments are selected and grouped in order to develop candidate payloads for design studies. Ideally, this match of payloads to spacecraft designs would be so perfect that all the major objectives of advanced payloads planning would be met, including the goals and objectives of the total research/experimentation program. Actually, this process is an imperfect one, thus we have had to develop a method whereby we could do agency-wide payload planning and produce products useful for both design studies and utilization studies. This method is called the Integrated Payload Planning Activity, (IPPA).

INTEGRATED PAYLOAD PLANNING ACTIVITY

I. METHODOLOGY TO ACCOMPLISH SPACE STATION PAYLOAD PLANNING AND DEFINITION STUDIES

II. INVOLVES THREE PRINCIPAL FUNCTIONS

- PAYLOAD ANALYSIS
- PAYLOAD SYNTHESIS
- PAYLOAD - MISSION MATCHING

III. PROVIDES PROGRAM PLANNING AND DESIGN PRODUCTS

- ALTERNATE PAYLOAD - MISSION MATCHES
- PAYLOAD - MISSION EFFECTIVENESS ANALYSES
- CONCEPT COMPARISON ANALYSES
- COST - SCHEDULE - RESOURCE REQUIREMENTS
- CREW SKILLS AND MIXES REQUIREMENTS

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9-8-69

SLIDE 4

INTEGRATED PAYLOAD PLANNING ACTIVITY

IPPA is a methodology and as such involves the efforts of a number of people and organizations - combining the work into a useful process by which the planning products can be developed and applied to studies and design effort. Of the products listed the alternate payload-mission matches, concept comparison analyses and cost-schedule-resources requirements have proven most useful. As design effort progresses beyond the definition phase payload-mission effectiveness and crew skills-mixes analyses becomes more important.

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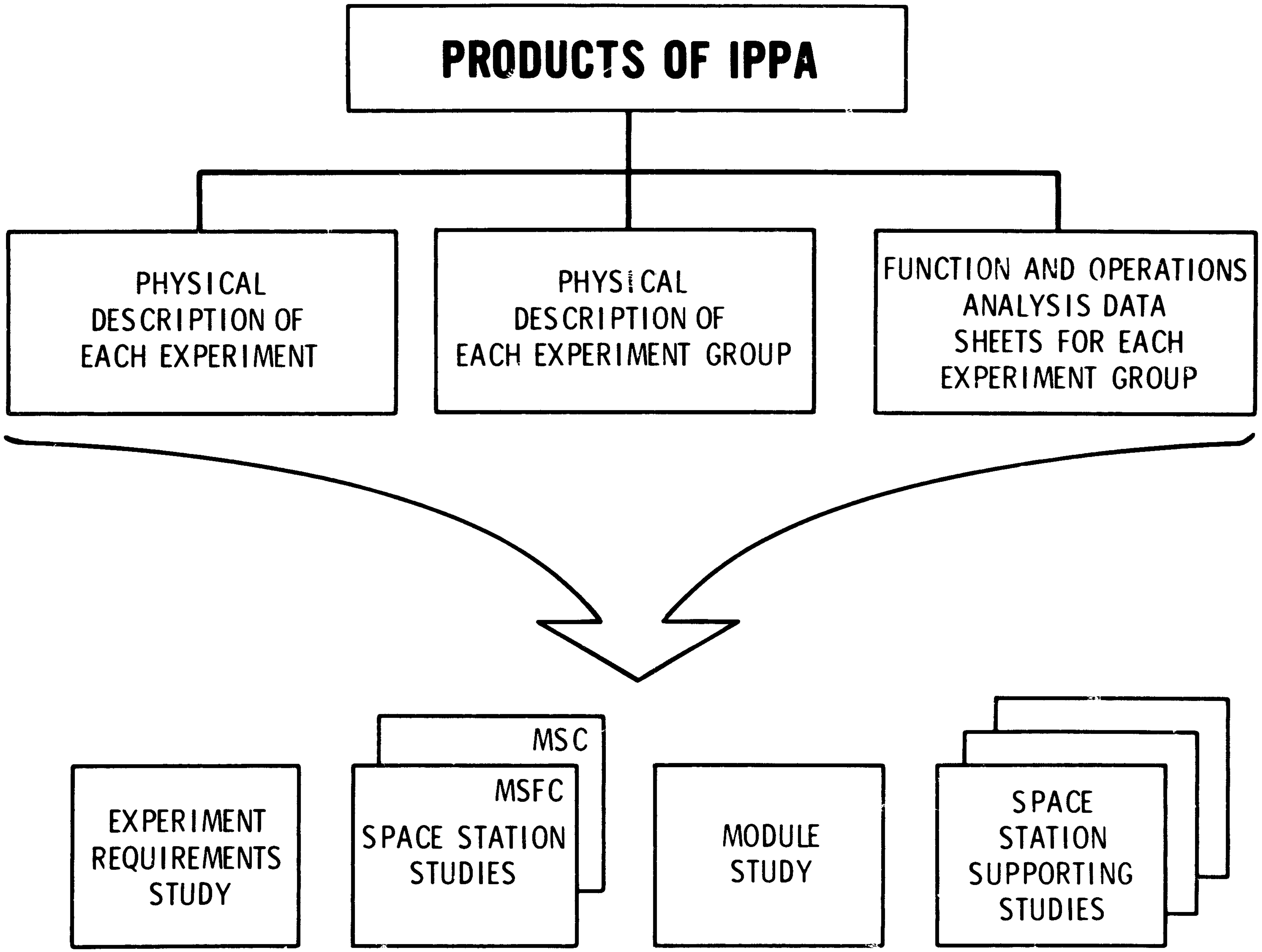

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SLIDE 5

PRODUCTS OF IPPA

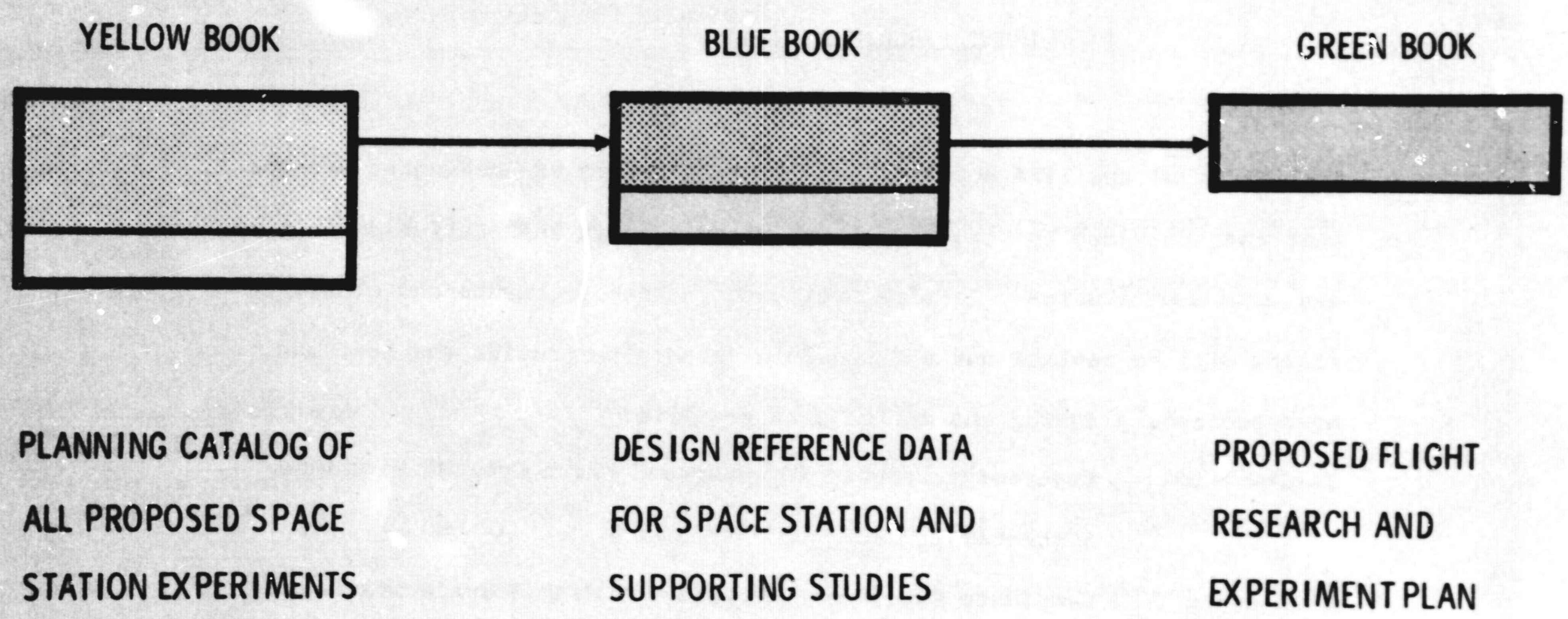
The output of the IPPA activity has led to a series of documents, perhaps best characterized by the Blue Book, which support the station definition and ancillary studies. As time progresses, these documents and others to follow will be revised and updated as necessary to provide the best and most accurate planning and design data possible.

Yellow Book: Experiment Program for extended Earth Orbital Missions, September 1, 1969

Blue Book: Candidate Experiment Program for Manned Space Stations, September 15, 1969

Green Book: Baseline Research and Experiment Program for the Earth Orbital Space Station, April 1, 1970

SPACE STATION EXPERIMENT PROGRAM DOCUMENT RELATIONSHIPS



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5-20-70

SLIDE 6

EXPERIMENT PROGRAM DOCUMENTS

The Yellow and Blue Books described earlier have been followed by a Green Book which describes the cost and schedule data for the Blue Book. It serves as the program reference document in terms of depicting the kinds of experiments and research capabilities we hope to develop for the space station. At the present time this document is under review and study by the sponsoring program offices in order to obtain their views regarding estimated flight priorities, costs and schedules. These comments, when incorporated into the Green Book, will constitute the initial Agency plan for Space Station utilization. The international community of users will also be requested to comment on the Green Book.

CONTENTS OF CANDIDATE EXPERIMENT PROGRAM

DISCIPLINE	FPE NO.	FPE NAME
ASTRONOMY	5.1	GRAZING INCIDENCE X-RAY TELESCOPE
	5.2A	ADV. STELLAR ASTRONOMY MODULE
	5.3A	ADV. SOLAR ASTRONOMY MODULE
	5.4	UV STELLAR SURVEY
	5.5	HIGH-ENERGY STELLAR SURVEY
SPACE PHYSICS	5.6	SPACE PHYSICS AIRLOCK EXPERIMENTS
	5.7	PLASMA PHYSICS AND ENVIRONMENT PERTURBATIONS
	5.8	COSMIC RAY PHYSICS LABORATORY
SPACE BIOLOGY	5.9	SMALL VERTEBRATES (BIO D)
	5.10	PLANT SPECIMENS (BIO E)
	5.25	MICROBIOLOGY (BIO C)
	5.26	INVERTEBRATES (BIO F)
EARTH SURVEYS	5.11	EARTH SURVEYS
	5.12	REMOTE MANEUVERING SUBSATELLITE

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CONTENTS - CANDIDATE EXPERIMENT PROGRAM

During the early phases of experiment planning for the space station, a natural trend to combine experiments into groupings was followed and the term, Functional Program Element was coined to represent such groupings. The two primary characteristics of these groupings, or FPE'S are the similar and related demands they impose on the Space Station for support and accommodation and the interrelated and complementary contributions they make to the experiment goals and objectives. This listing represent, the contents of the Blue Book, and corresponds with the major FPE'S used to support the Space Station design effort.

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CONTENTS OF CANDIDATE EXPERIMENT PROGRAM (CONT'D)

DISCIPLINE	FPE NO.	FPE NAME
AEROSPACE MEDICINE	5.13C	CENTRIFUGE
	5.13	BIOMEDICAL AND BEHAVIORAL RESEARCH
	5.14	MAN/SYSTEM INTEGRATION
	5.15	LIFE SUPPORT AND PROTECTIVE SYSTEMS
SPACE MANUFACTURING	5.16	MATERIALS SCIENCE AND PROCESSING
ADVANCED TECHNOLOGY	5.17	CONTAMINATION MEASUREMENTS
	5.18	EXPOSURE EXPERIMENTS
	5.19	EXTENDED SPACE STRUCTURE DEVELOPMENT
	5.20	FLUID PHYSICS IN MICROGRAVITY
	5.22	COMPONENT TEST AND SENSOR CALIBRATION
ENGINEERING/ OPERATIONS	5.24	MSC FLIGHT OPERATIONS PACKAGE

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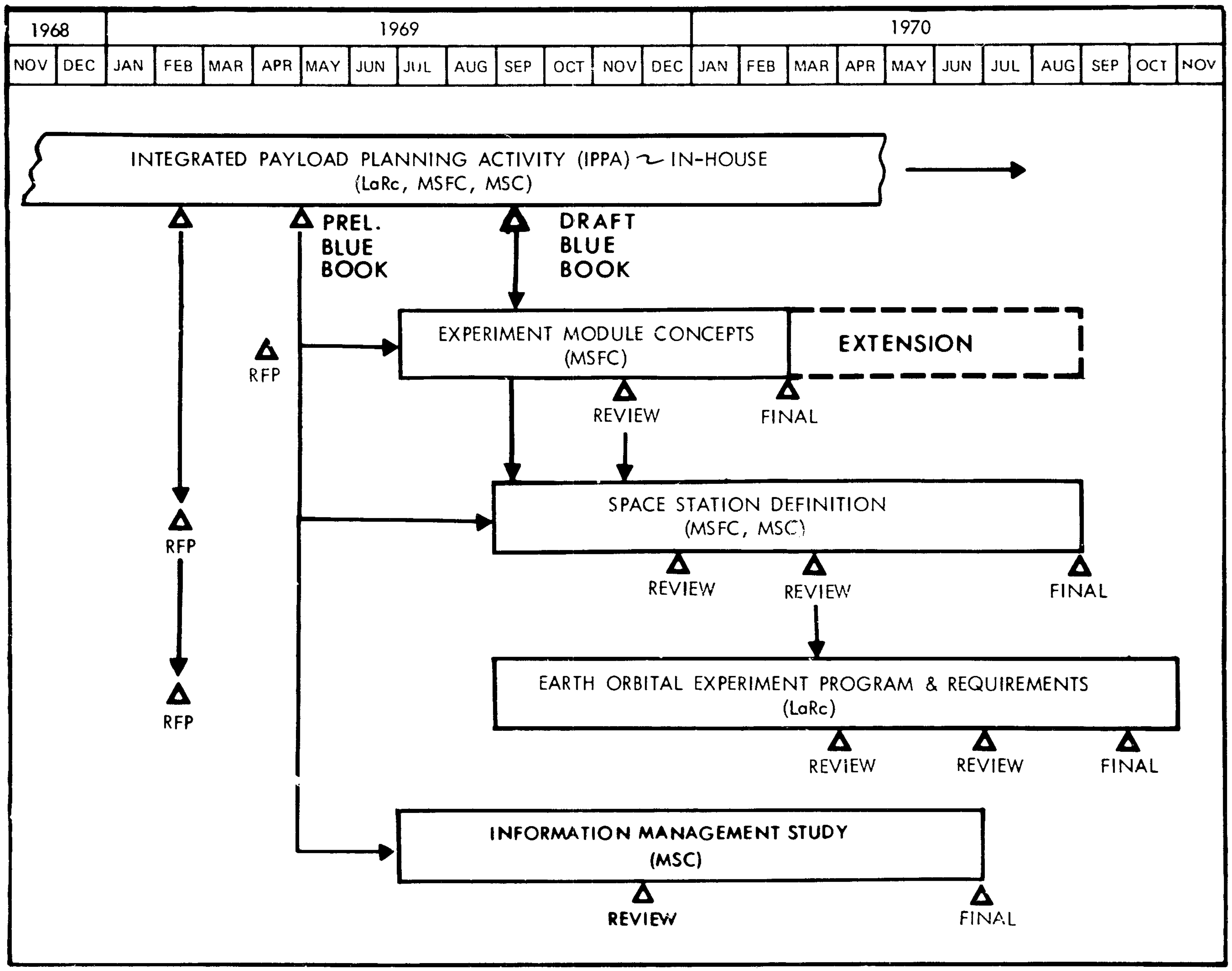
CONTENTS - CANDIDATE EXPERIMENT PROGRAM

In many cases, the FPE is quite analogous to an entire experiment module or facility, for example: FPE 5.2 Stellar Astronomy comprises a large 2 to 3 meter diffraction limited telescope. FPE 5.8 consists of a high energy cosmic ray laboratory. This comparison though not always a perfect one indicates that some 15 modules or facilities have been identified with the Space Station as candidate laboratories for use with the station.

SPACE STATION EXPERIMENT PROGRAM STUDY RELATIONSHIPS



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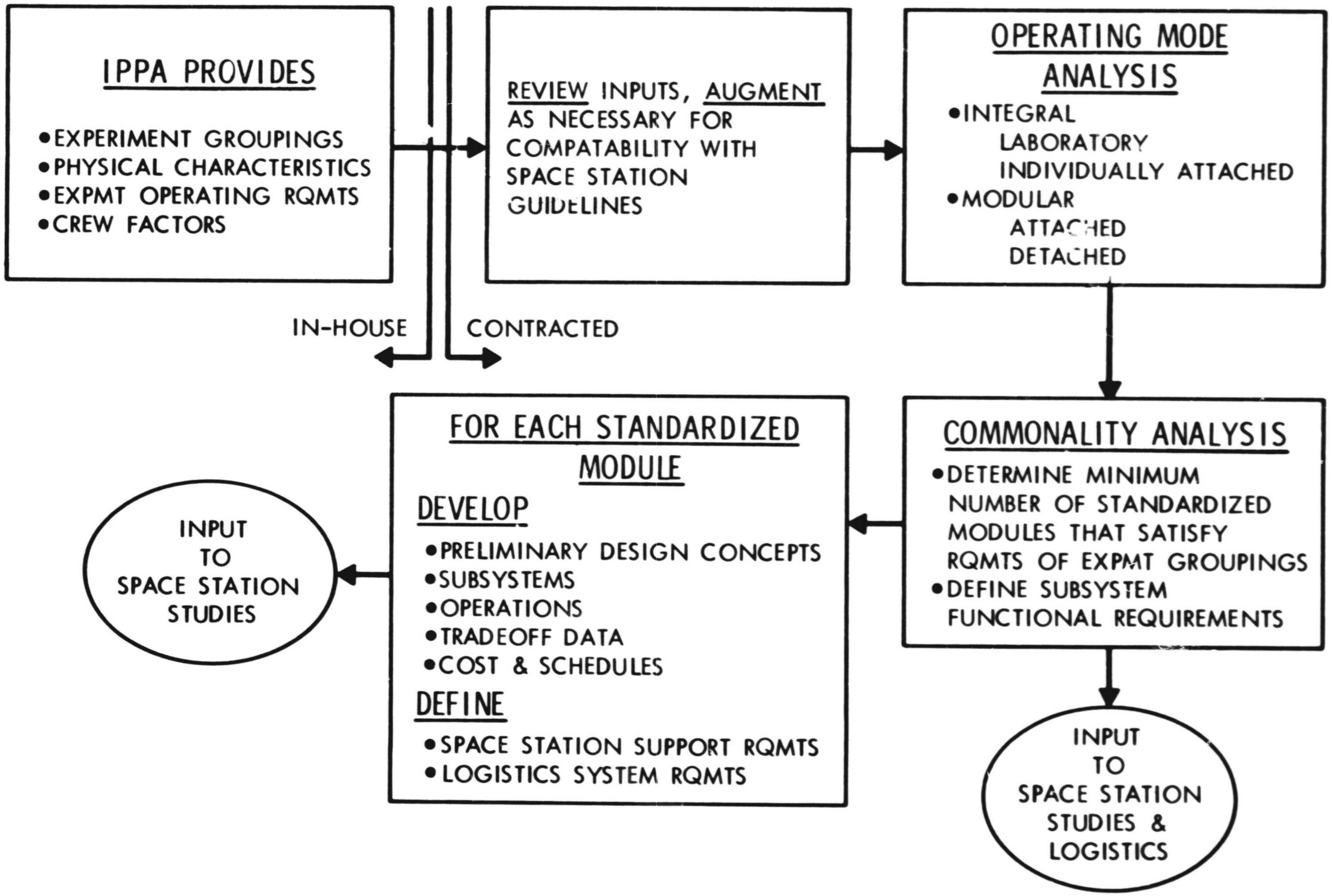
EXPERIMENT STUDY RELATIONSHIPS

This slide depicts the relationships between the definition studies, the ancillary or supporting studies and IPPA. Note the cross-feed of experiment design data and requirements among the several studies. By making the Blue Book a source document for the experiment portion of these studies, we have been able to compare the studies from the common thread of the experimentation/research program.

STUDY LOGIC FOR EXPERIMENT MODULE CONCEPTS



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EXPERIMENT MODULE CONCEPTS STUDY

Mr. Lord has described this study in an earlier presentation. In this and subsequent discussions one important part of the study-the commonality concepts analysis will be presented to show how significant cost reduction in the experiment program can be achieved through the use of common modules.

NASA CANDIDATE EXPERIMENT PROGRAM

ASTRONOMY	SPACE PHYSICS	SPACE BIOLOGY	EARTH APPLICATIONS	BIOMEDICINE & BIOTECHNOLOGY	MATERIALS SCIENCE	ADVANCED TECHNOLOGY	ENGINEERING & OPERATIONS
GRAZING INCIDENCE X-RAY TEL.	AIRLOCK EXPERIMENTS	SMALL VERTEBRATES (BIO D)	EARTH SURVEYS	BIOMEDICAL & BEHAVIORAL RESEARCH	MATERIALS SCIENCE & PROCESSING	CONTAMINATION MEASUREMENTS	MSF ENG. & OPERATIONS
ADVANCED STELLAR	PLASMA PHYSICS & ENVIRONMENTAL PERTURBATION	PLANT SPECIMENS (BIO E)	REMOTE MAN. SUBSATELLITE	CENTRIFUGE		EXPOSURE EXPERIMENTS	
ADVANCED SOLAR	COSMIC RAY PHYSICS LAB	PRIMATES (BIO A)		MAN/SYSTEM INTEGRATION		EXTENDED SPACE STRUCTURE DEVELOPMENT	
IR STELLAR SURVEY	PHYSICS & CHEMISTRY LAB	MICROBIOLOGY (BIO C)		LIFE SUPPORT & PROTECTIVE SYSTEMS	FLUID PHYSICS IN MICROGRAVITY	COMPONENT TEST & SENSOR CALIB.	
UV STELLAR SURVEY		INVERTEBRATES (BIO F)				ADVANCED SPACECRAFT SYS. TESTS	
HIGH-ENERGY STELLAR							

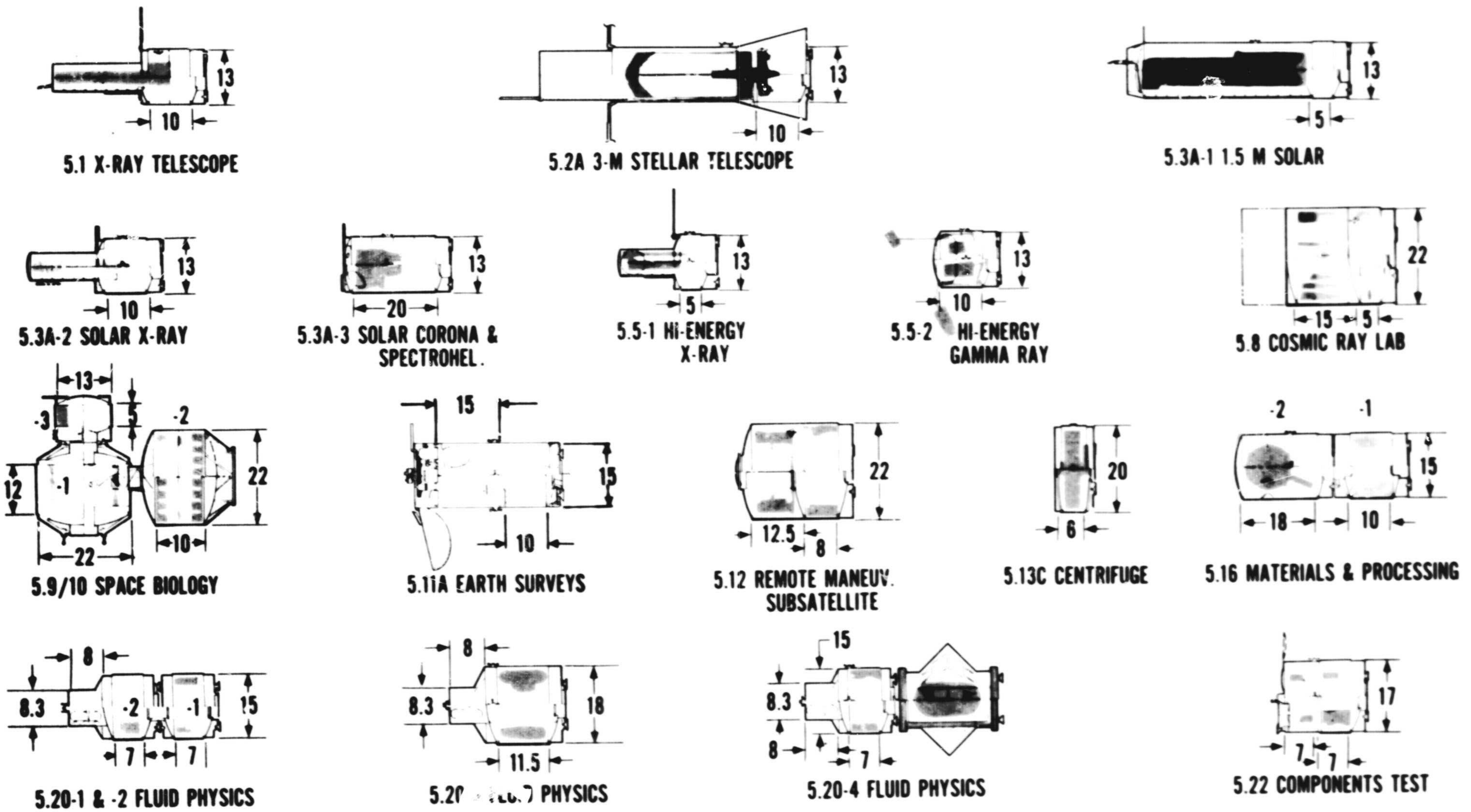
CANDIDATE MODULAR EXPERIMENT GROUPINGS

SLIDE 11

NASA CANDIDATE EXPERIMENT PROGRAM

The chart shows the NASA Candidate Experiment Program for Manned Space Stations. All Functional Program Elements (FPE) shown boxed were used to develop design criteria for experiment module concepts.

EXPERIMENT MODULE CONCEPTS FOR TOTAL PROGRAM



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EXPERIMENT MODULE CONCEPTS FOR TOTAL PROGRAM

Approximately thirty individual modules were conceptually designed for the various experiments. This includes alternative configuration arrangements and, in the case of Earth Surveys, modules designed for different operating modes (attached/detached). Shown here are the chosen twenty-one experiment module concepts that have been individually designed to accomplish the total experiment program. Module diameter and sidewall dimensions are shown.

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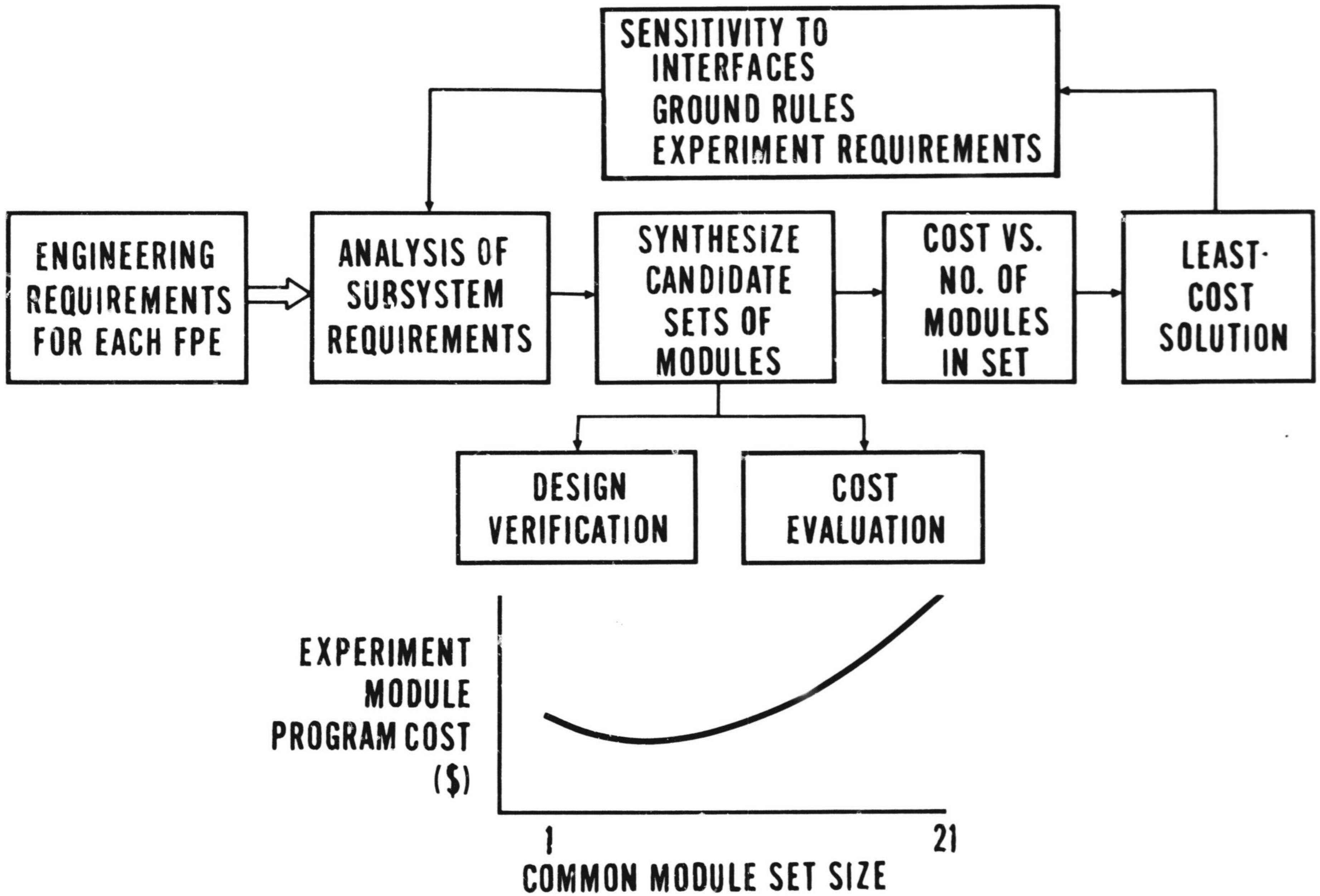
COMMONALITY APPROACH



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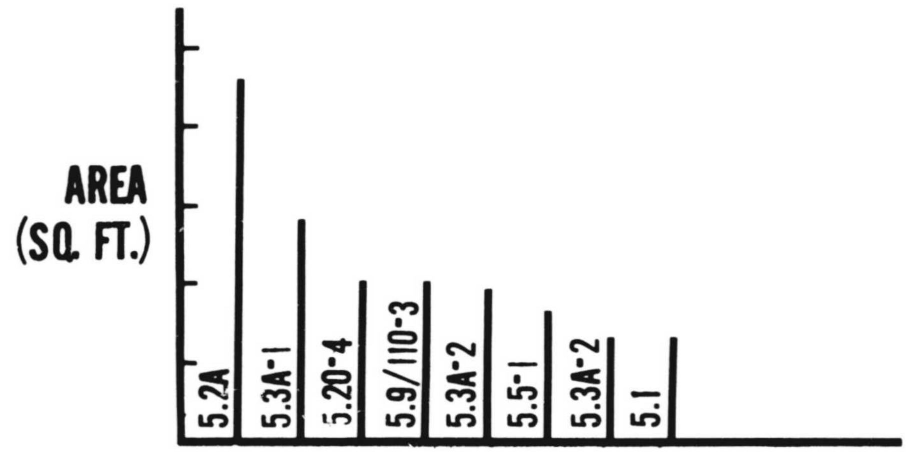
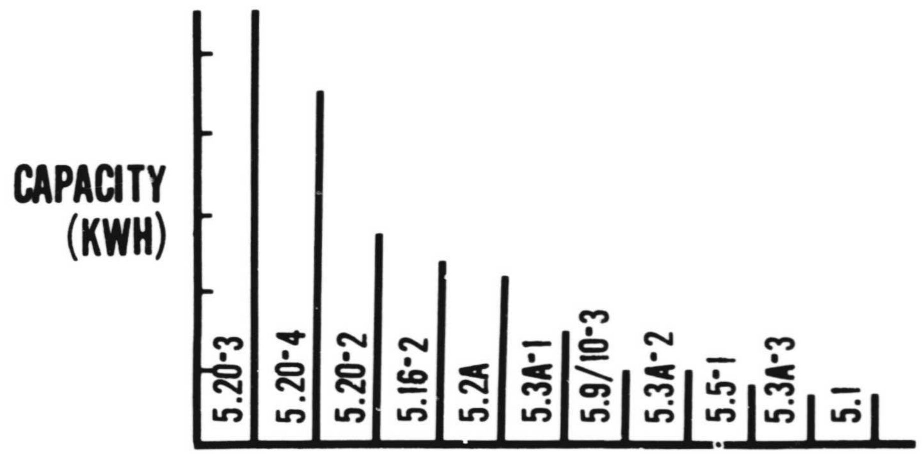
COMMONALITY APPROACH

The Commonality Analysis objective is to examine the custom module concepts to determine if experiment program costs can be minimized through the use of common modules. A common module is defined as one whose configuration and subsystems permit it to accommodate any one of a group of FPE considered in its synthesis. Thus, the degree of commonality ranges from a single concept to accommodate all FPEs to custom designed modules for each FPE. The high cost for custom designed modules is due to the nonrecurring costs associated with multiple development programs. A single module concept minimizes nonrecurring costs but results in cost penalties associated with the excess capabilities of oversized and/or overdesigned subsystems. The commonality analysis procedure identified a minimum in the curve between these two points.

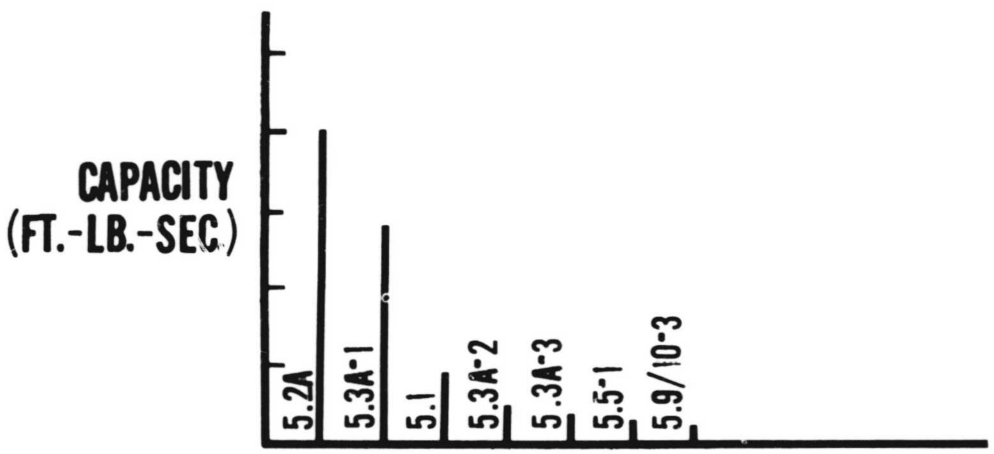
SUBSYSTEM REQUIREMENTS



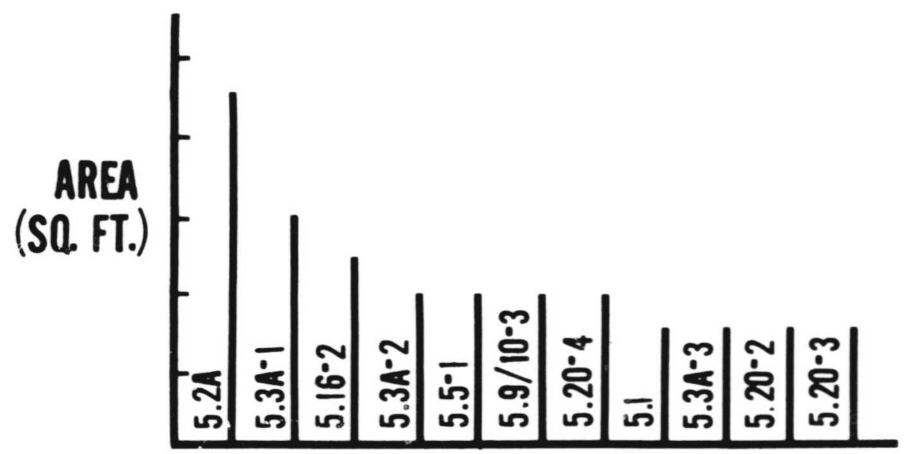
SOLAR ARRAY



BATTERY SYSTEM



CONTROL MOMENT GYROS



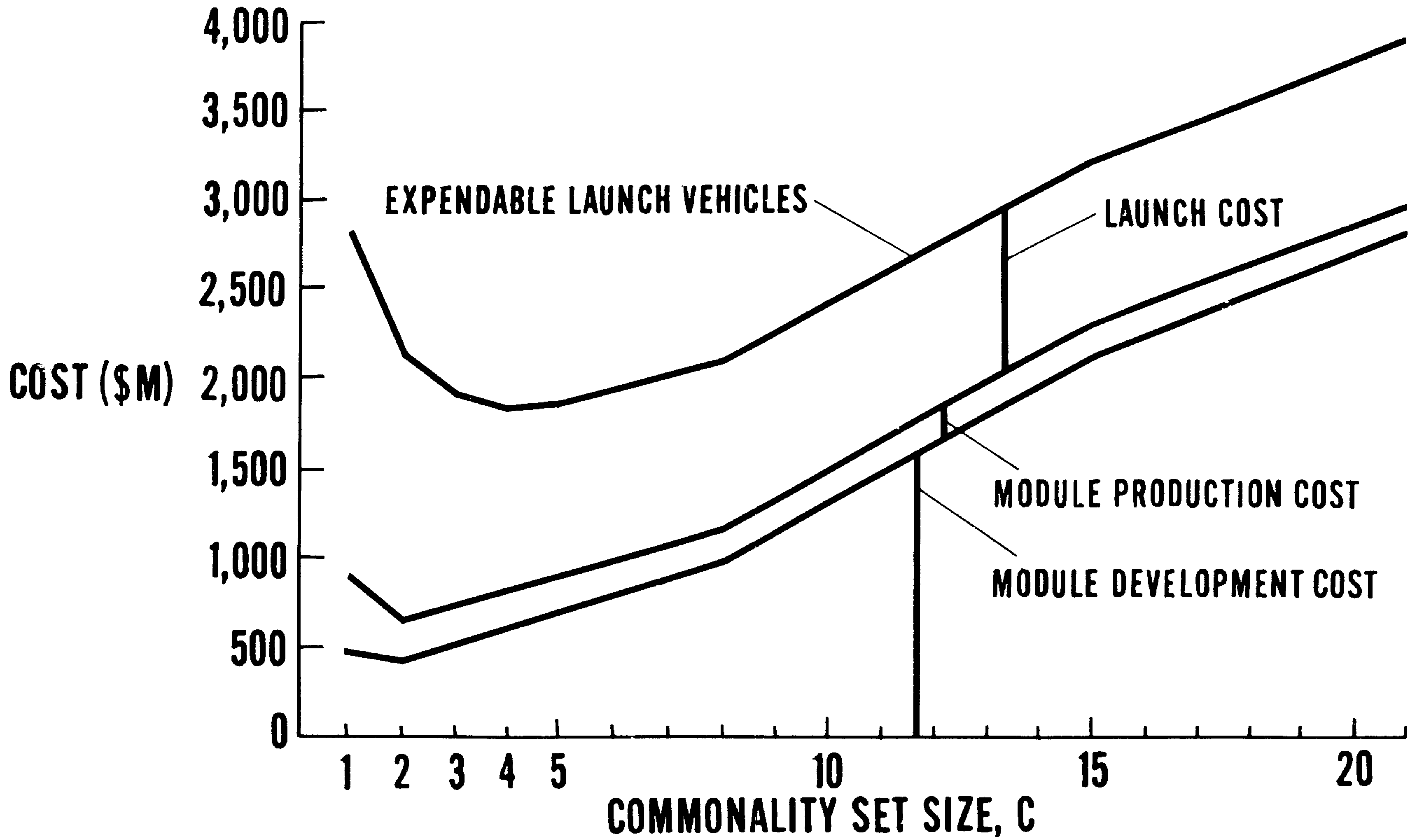
ECS RADIATORS

SLIDE 14

SUBSYSTEM REQUIREMENTS

These graphic displays show subsystem requirements for detached operating modules. The data were used to analyze subsystem requirement levels for common modules assigned to groupings of these FPEs.

COMMON MODULE PROGRAM COST



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COMMON MODULE PROGRAM COST

This chart presents a breakdown of major common module program costs versus the commonality sets investigated in the analysis. It is shown in layer cake fashion so that the top layer is representative of the program cost.

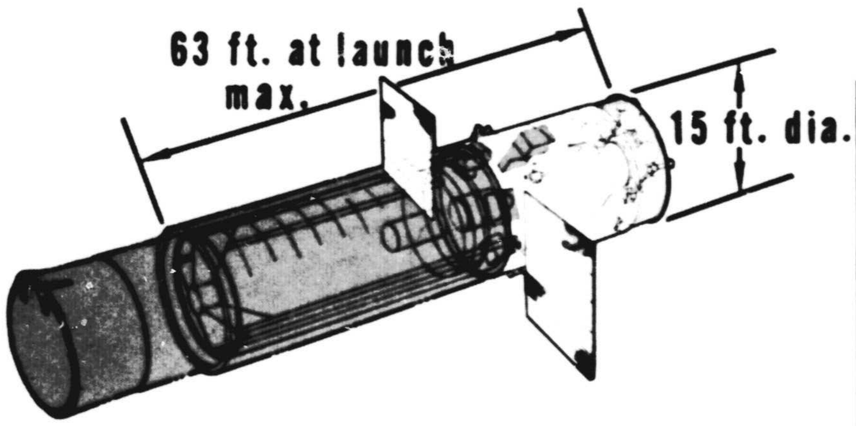
Module development costs for the C1 set are high because of the difficult technical problems as well as the large complex module necessary to meet all FPE requirements. Development costs for the two modules of the C2 set are slightly less, but the development cost rises monotonically thereafter to that incurred in a C21 set having 21 separate development programs. The production cost shown is the total production costs for 21 modules of the appropriate type. The C1 module sets are again large because of the size and complexity of the module. Production costs decrease monotonically thereafter as the modules become more and more tailored to the individual FPE requirements and there is less and less unused capability.

Launch costs are shown for all expendable vehicles. The launch costs for the

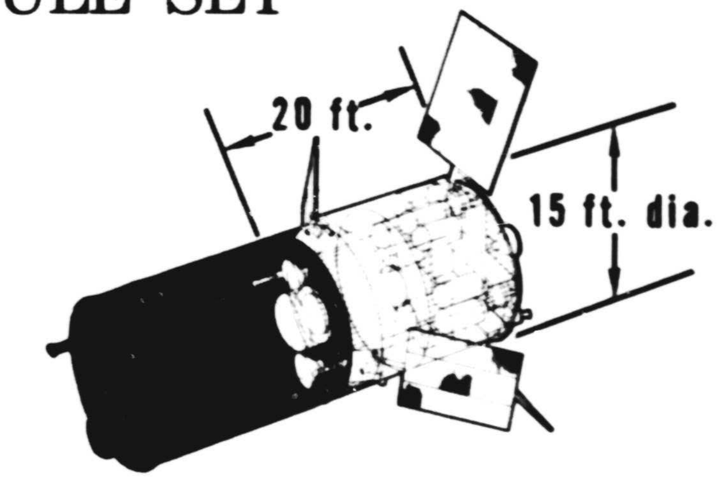
COMMON MODULE PROGRAM COST (continued)

low-number commonality sets are very high because of the module size and weight require expensive launch vehicles. This cost decreases as the modules become smaller and lighter in the higher-number commonality sets. The launch costs turn out to be near-minimum in the C4-C5 area and will decrease very little thereafter. The conclusion may be reached that because (1) the experiment module development cost rise is greater than the experiment module production cost reduction with increasing number commonality sets and (2) the launch costs are near minimum in the C4 area, that therefore the minimum cost module set occurs in the C4-C5 area.

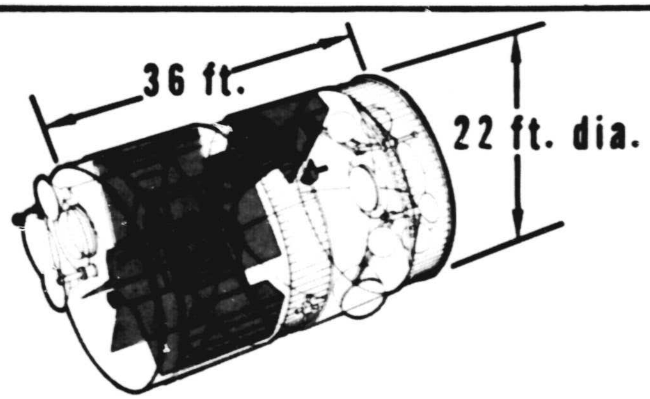
INITIAL COMMON MODULE SET



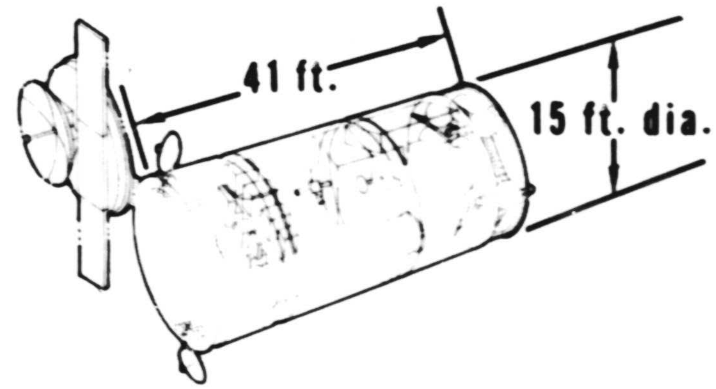
COMMON MODULE NO. 1
Detached, finepointing, low-g



COMMON MODULE NO. 2
Detached, propulsion unit



COMMON MODULE NO. 3
Attached, 22 ft. dia. laboratory



COMMON MODULE NO. 4
Attached, 15 ft. dia. laboratory

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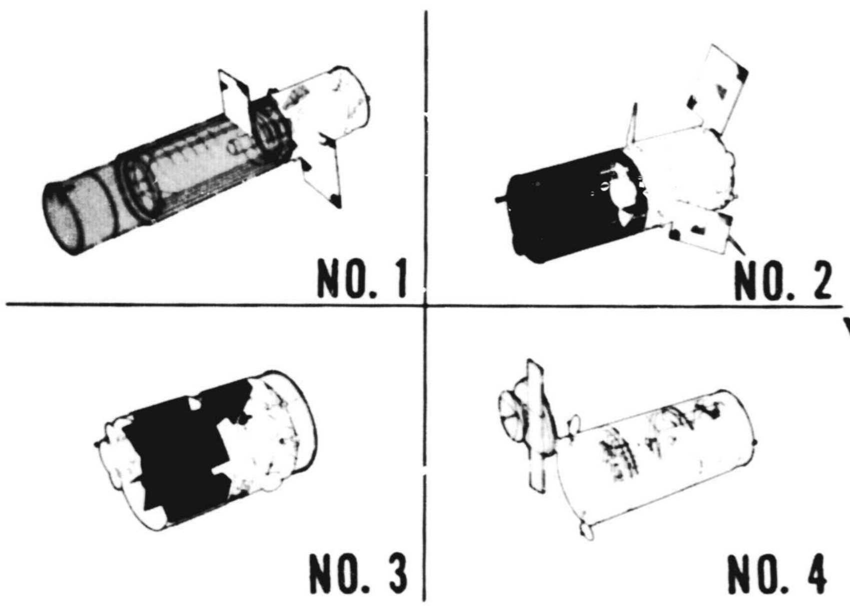
INITIAL COMMON MODULE SET

The initial common module set of four shown has the capability of implementing the Candidate Experiment Program used as a baseline input to the study. Nine of the No. 1 modules, two of No. 2, four of No. 3, and six of No. 4 were required. The first module, caters to fine-pointing and low-g requirements in a detached mode. The second provides long term, low-level acceleration thrusting for a category of fluid physics experiments in a detached mode. The third and fourth house experiments operated in an attached mode and vary in size and configuration. The 22-foot diameter module was sized by experiment equipment dimensions.

GENERAL DYNAMICS
Convair Division

COMMON MODULE SENSITIVITY

BASELINE COMMON MODULE SET



DRIVE
DOWN
COSTS

GROUND RULES
EXPERIMENT REQUIREMENTS
MODULARITY

EXPERIMENT REASSIGNMENT
EXPERIMENT TO MODULE INTERFACE
LAUNCH VEHICLE COMPATIBILITY

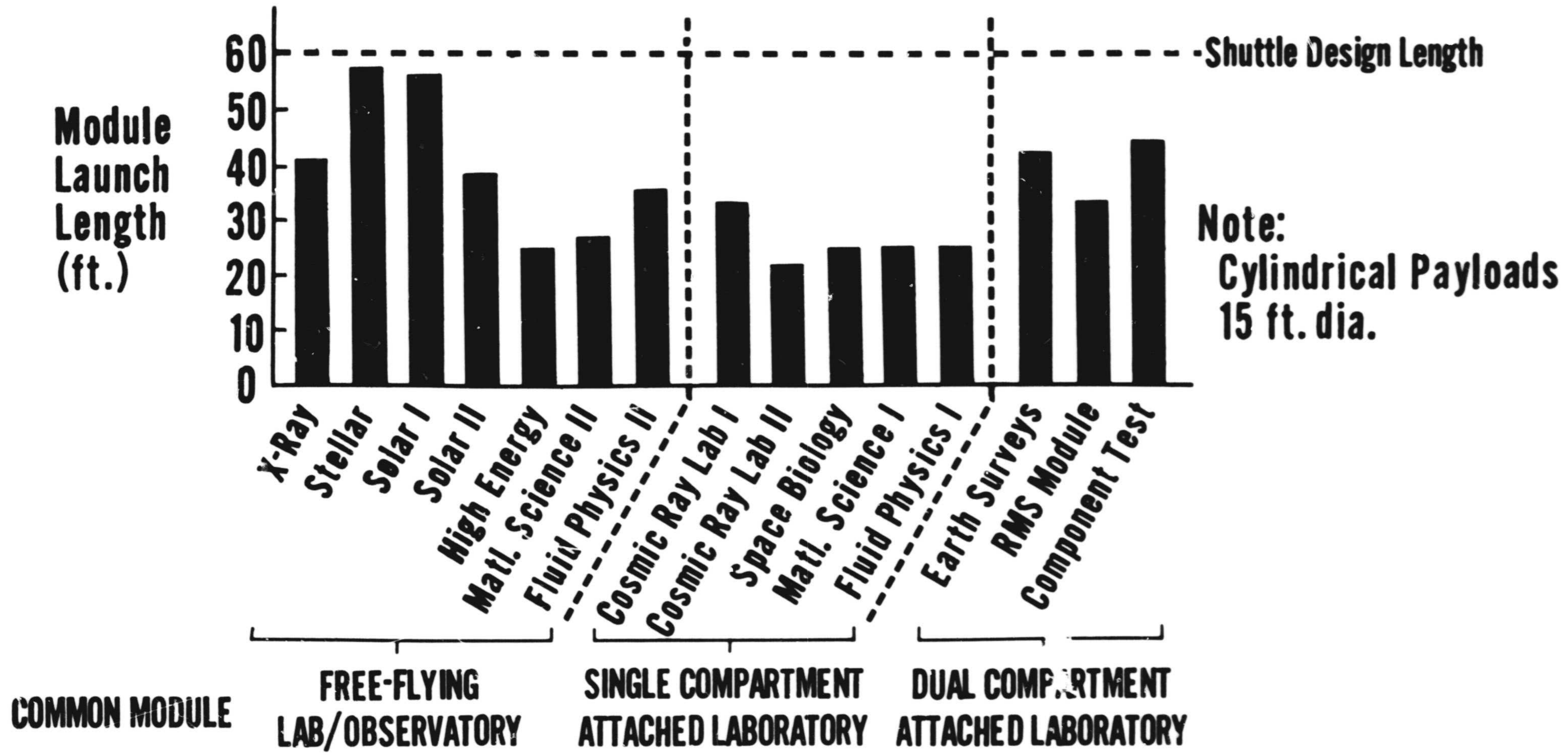
REVISED COMMON MODULE SET

SLIDE 17

COMMON MODULE SENSITIVITY

The common module set derived during the first portion of the study effort was subjected to sensitivity analyses aimed at driving down costs. The items listed on the chart represent areas examined during the analyses. This resulted in the revised common module set to be described later.

EXPERIMENT MODULE LENGTH REQUIREMENTS ON LAUNCH VEHICLES



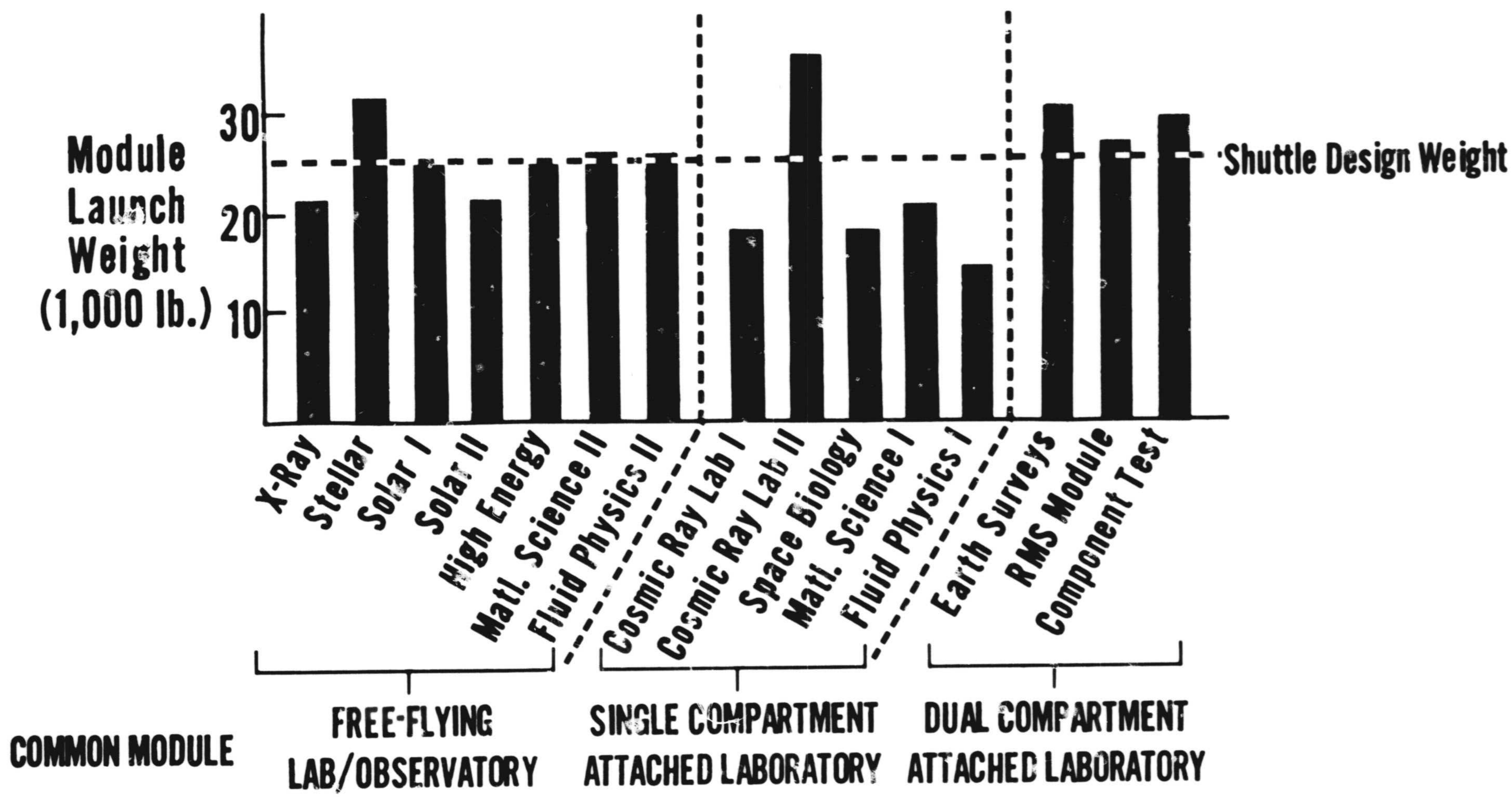
SLIDE 18

EXPERIMENT MODULE LENGTH REQUIREMENTS ON LAUNCH VEHICLES

Experiment module lengths are shown. All are within the current shuttle bay design length of 60 feet and diameter of 15 feet. The common module outside diameters are 14 feet, seven inches, with a pressure shell diameter of 14 feet.

Sensitivity analysis caused a reduction in the number of module concepts from 21 to 15.

EXPERIMENT MODULE WEIGHT REQUIREMENTS ON LAUNCH VEHICLES



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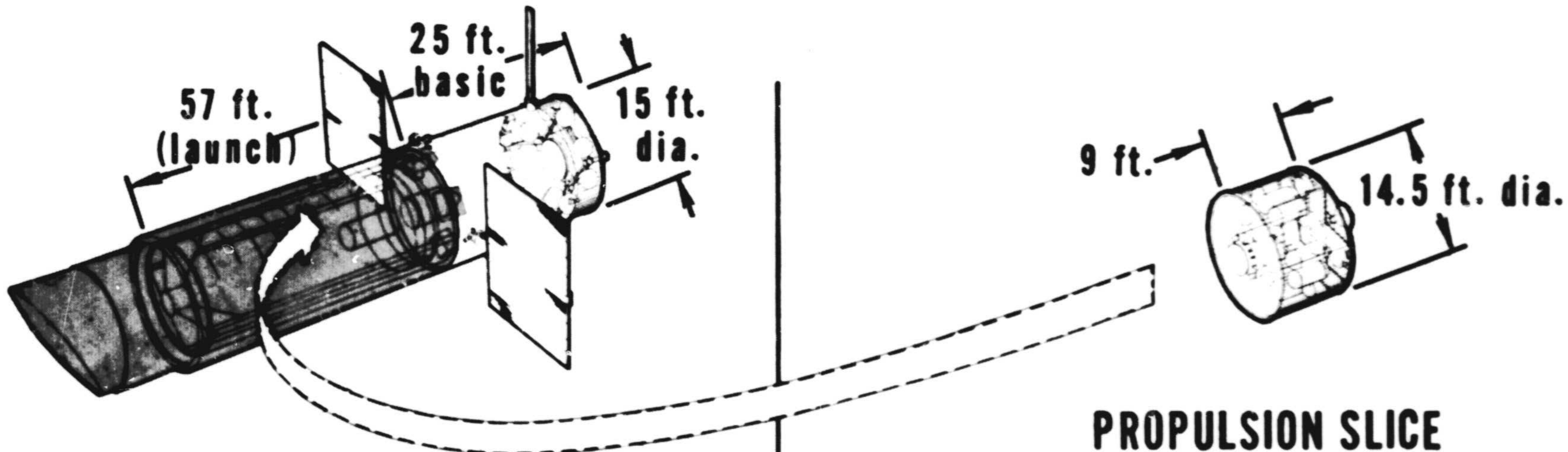
EXPERIMENT MODULE WEIGHT REQUIREMENTS ON LAUNCH VEHICLES

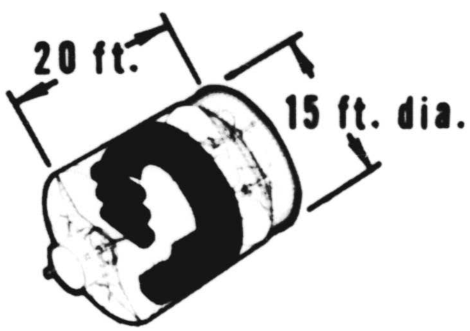
Launch weight estimates are provided for each experiment module. It should be noted that a 10% pad and a 30% growth factor was assumed for module subsystems and structure during this phase of the study. These weights are based on shuttle or internal fairing-type launch with no allowance for launch shrouds or adapters. Several modules are noted to exceed the shuttle design payload capability of 25,000 pounds suggesting a mix of shuttle and expendable launch vehicles. Further design and analysis may also provide innovative techniques for weight reduction.

REVISED COMMON MODULE SET

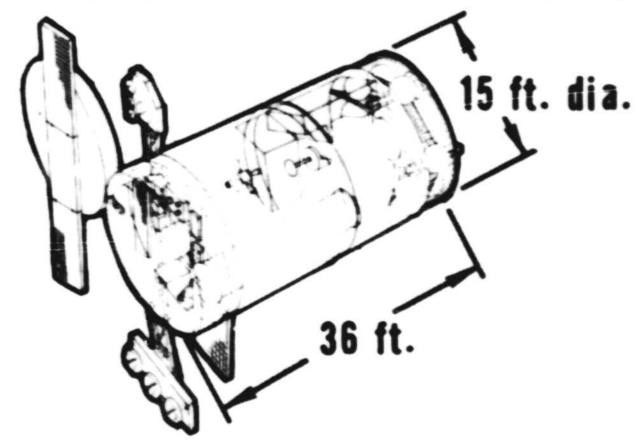


COMMON MODULE CM-1
Max. launch wt. 30,750 lb. (stellar astronomy)
Detached, finepointing, low-g

PROPULSION SLICE
Wt. 4,000 lb. dry
Add-on for detached thrusting experiments



COMMON MODULE CM-3
Max. launch wt. 31,800 lb. (cosmic ray lab)
Attached, 15-ft. dia., single-compt. laboratory



COMMON MODULE CM-4
Max. launch wt. 29,900 lb. (earth surveys lab)
Attached, 15 ft. dia., dual-compt. laboratory

SLIDE 20

REVISED COMMON MODULE SET

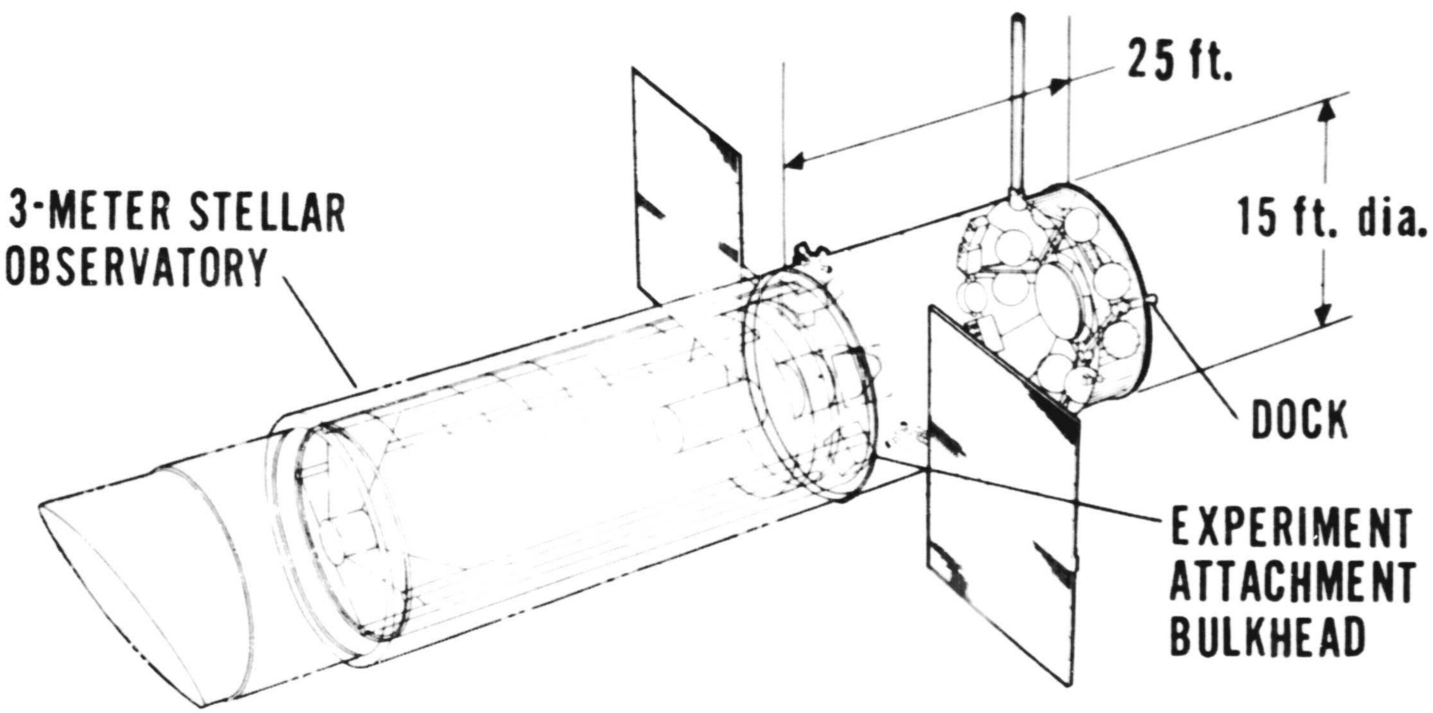
The free-flying common module CM-1 will accommodate experiment groups requiring detached operation.

The propulsion slice contains no subsystems other than the propulsion and enclosing structure. This slice would be attached to the experiment bulkhead of common module CM-1 for performance of the free-flying FPE 5.20 fluid physiscs experiments.

The CM-3 common module is a single-compartment lab module that docks and remains attached to the Space Station, which provides electrical power and environment gases to the module through the interface. Construction is similar to the other two common modules.

The CM-4 is similar in diameter and construction to the other two common modules. It is a two-compartment lab module which docks and remains attached to the Space Station. The experiment groups accommodated have larger volume requirements than those assigned to CM-3.

COMMON MODULE CM-1



EXPERIMENT GROUPS ACCOMMODATED

X-Ray	High-Energy Stellar
Stellar	Matl. Science & Proc.
Solar (2)	Fluid Physics

Max. Weight Bare	16,380 lb.
Weight Fitted*	30,750 lb. max.
	20,915 lb. min.

*Includes minimum propellant for rendezvous/dock

SLIDE 21

COMMON MODULE CM-1

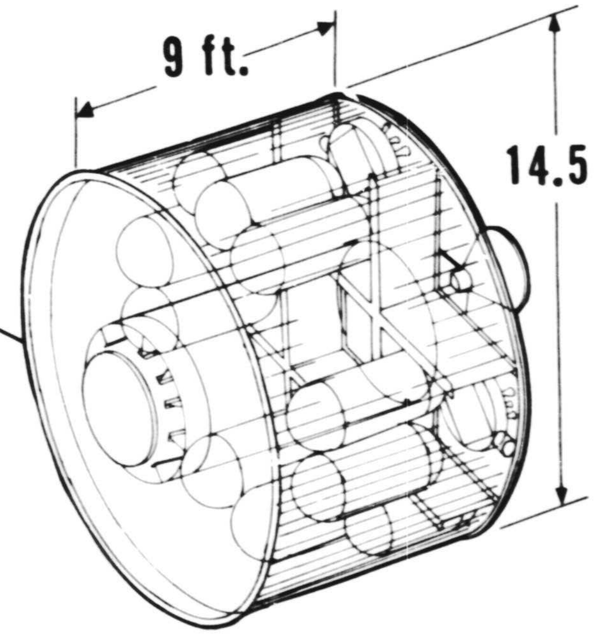
The free-flying common module CM-1 will accommodate any of the seven experiment groups listed. All these experiments are mounted on the end pressure bulkhead except the materials science and processing chamber, which is mounted on the side wall frames. Subsystems are mounted adjacent to the docking bulkhead and may be thermally shielded from the experiment components.

Basic structural shell, hatches, docks, and bulkhead attachments are similar to the other two common modules. Manned IVA access to critical subsystems components such as star trackers and drive motors for the solar cell arrays and bar electromagnets, is inherent to the maintenance design approach.

Modularization of subsystems allows the matching of performance capabilities with experiment requirements. In the case of the three-meter telescope shown, a stringent complement of module subsystems is required.

Single-degree-of-freedom solar cell panels may be retracted for clearance during Space Station docking operations.

PROPULSION SLICE



TOTAL IMPULSE	Monoprop. - 1.5×10^6 lb.-sec.	WEIGHTS	Structure	3,500 lb.
	Resistojet - 0.24×10^5 lb.-sec.		Subsystems	500 lb.
THRUST RANGE	30 to 0.03 lb.		Total	4,000 lb. dry

PROPELLANT CAPACITIES	Hydrazine	6,800 lb.
	Ammonia	690 lb.

SLIDE 22

PROPULSION SLICE

The propulsion unit contains no subsystems other than the propulsion and enclosing structure. This slice would be attached to the experiment bulkhead of common module CM-1 for performance of the free-flying FPE 5.20 fluid physics experiments.

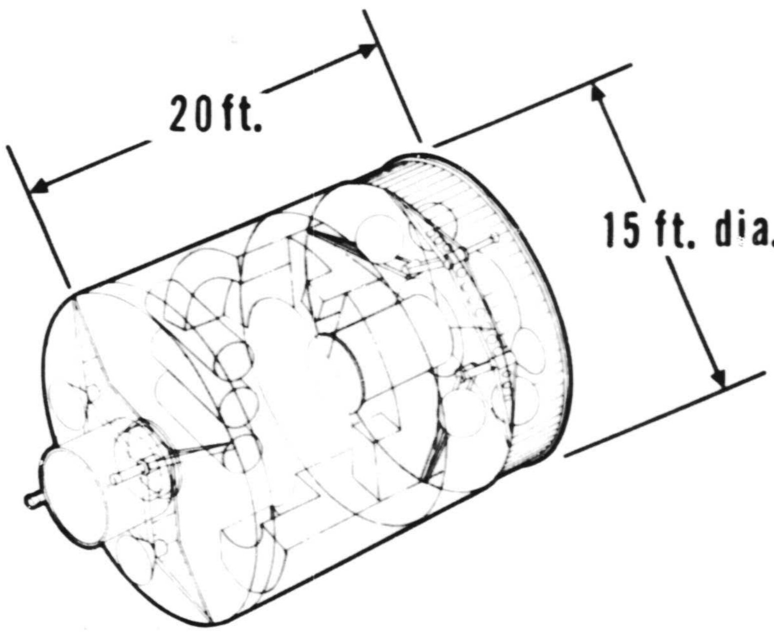
Thrust is provided by two gimballed engine clusters of hydrazine engines (3) and resistojet engines (1). Thrust levels are fixed. Tankage is provided for hydrazine, ammonia, and helium.

Structure consists of an outer shell with insulation and meteoroid shielding, a central five-foot-diameter access tunnel, and an end dock.

GENERAL DYNAMICS
Convair Division

COMMON MODULE CM-3

MATERIAL SCIENCE
EXPERIMENT SHOWN



EXPERIMENT GROUPS ACCOMMODATED

- Cosmic Ray Lab (2 Modules)
- Space Biology Lab
- Material Science & Proc. Lab
- Fluid Physics Lab

Max. Weight Bare	12,580 lb.
*Weight Fitted	31,800 lb. max.
	13,300 lb. min.

*Includes minimum propellant for rendezvous/dock

SLIDE 23

COMMON MODULE CM-3

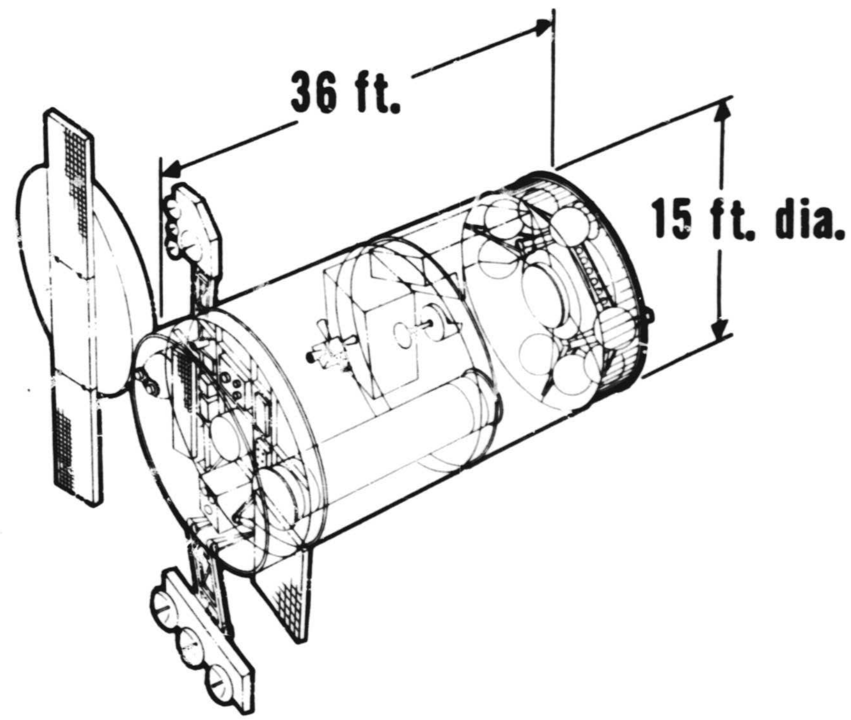
The CM-3 common module is a single-compartment lab module that docks and remains attached to the Space Station, which provides electrical power and nvironment gases to the module through the interface. Construction is similar to the other two common modules.

Two CM-3 modules are required for the cosmic ray experiments: one for the control center and one for the experiment bays. The other experiment groups require docks at both ends of the module, utilizing commonality of appropriate structures.

Unique to this lab module is a tunnel within the module which can be used as an airlock between the module and space station.

COMMON MODULE CM-4

EARTH SURVEYS
EXPERIMENT SHOWN



EXPERIMENT GROUPS ACCOMMODATED

- Earth Surveys
- Remote Maneuvering Subsatellite Module
- Component Test & Sensor Calibration Lab
- Biomedical Group

Weight Bare	16,450 lb.
*Weight Fitted	29,900 lb. max.
	26,150 lb. min.

*Includes minimum propellant for rendezvous/dock

SLIDE 24

COMMON MODULE CM-4

The CM-4 is similar in diameter and construction to the other two common modules. It is a two-compartment lab module which docks and remains attached to the Space Station. The four experiment groups accommodated include the alternate biomedical group of experiments. These experiment groups have larger volume requirements than those accommodated in CM-3.

A major configuration driver for CM-4 is the Component Test and Sensor Calibration experiment group. This experiment group results in the requirement for a tunnel airlock and seven-foot-diameter hatch in the second compartment, which adds considerable structural weight and complexity. The hatch is used in the RMS module application, however, as a launch opening for the subsatellites. Volumetric requirements for the earth surveys experiments are another major driver.